

(DIRS 118952-Savage, Svarc, and Prescott 1999, all). After correction for deformation associated with the Little Skull Mountain earthquake, the data continue to indicate a strain rate about an order of magnitude lower than that reported by DIRS 103485-Wernicke et al. (1998, all).

DOE is continuing to fund additional investigations on the crustal strain rate in the Yucca Mountain region through a grant to the University of Nevada. Dr. Wernicke of the California Institute of Technology (Cal Tech) continues to monitor conditions as a principal investigator under a subcontract, and a group at the University of Nevada at Reno is tasked with providing an independent evaluation of the assumptions and processing that support the Cal Tech results. This study involves 32 geodetic monument sites with continuous Global Positioning System measurements, a significant improvement over the study reported in *Science* in 1998. The first report (DIRS 156302-Marks 2001, all) from this effort was issued during 2001 and provided a status based on data collected through May 2001. According to the report, preliminary findings from this ongoing study are that strain is accumulating in the Yucca Mountain region, but at a notably lower rate than previously reported by DIRS 103485-Wernicke et al. (1998, all). Improved results are expected over the next year of the study, including a better characterization and explanation for the strain accumulation. DOE believes the results of this study will confirm the lower crustal strain rates as reported by the U.S. Geological Survey. However, if higher crustal strain rates are shown to exist, DOE will reassess the volcanic and seismic hazard at Yucca Mountain.

3.1.3.4 Mineral and Energy Resources

The southern Great Basin contains valuable or potentially valuable mineral and energy resources, including deposits with past or current production of gold, silver, mercury, base metals, and uranium. The proximity of known deposits and the identification of similar geologic features at Yucca Mountain have led some investigators to propose that the analyzed Yucca Mountain land withdrawal area (see Figure 3-2) could have the potential for mineral resources (DIRS 103483-Weiss, Noble, and Larson 1996, p. 5-26).

DOE site investigations included evaluation of the potential for mineral and energy resources in the analyzed withdrawal area because the presence of such resources could lead to exploration and inadvertent *human intrusion* (see Chapter 5). The *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000, Section 4.9) describes results of investigations that address relevant natural resources. Site characterization investigators identified no economic deposits of base or precious metals, industrial rocks or minerals, and energy resources, based on present use, extraction technology, and economic value of the resources (DIRS 151945-CRWMS M&O 2000, p. 4.9-12 to 4.9-14). DOE believes the potential for economically useful mineral or energy resources in the analyzed Yucca Mountain withdrawal area is low.

3.1.4 HYDROLOGY

This section describes the current hydrologic conditions in the Yucca Mountain region in terms of surface-water and groundwater system characteristics. The region of influence considered for surface water includes construction or land disturbance areas that could be susceptible to erosion, areas affected by permanent changes in surface-water flow, and areas downstream of the proposed repository that could be affected by eroded soil or potential spills of contaminants. The groundwater region of influence includes aquifers that would underlie areas of construction and operation, aquifers that could be sources of water for construction and operations, and aquifers downgradient of the proposed repository that repository use, including long-term releases, could affect. Section 3.1.4.1 describes surface-water conditions, and Section 3.1.4.2 describes groundwater conditions.

The hydrologic system in the Yucca Mountain region is characterized and influenced by a very dry climate, limited surface water [annual average precipitation of about 10 to 25 centimeters (4 to 10 inches) (Section 3.1.2.2), potential evaporation of almost 170 centimeters (66 inches) per year (DIRS 101779-DOE 1998, Volume 1, p. 2-29)], and deep aquifers. Important characteristics of the hydrologic system include drainages and streambeds, streams, springs, and playa lakes. In addition, water quantity and quality are important characteristics. Yucca Mountain is in the Alkali Flat-Furnace Creek groundwater basin of the larger Death Valley Regional Groundwater Flow System. Death Valley is a terminal hydrologic basin; surface water and groundwater cannot leave except by *evapotranspiration* (DIRS 100465-Luckey et al. 1996, p. 30). Important characteristics of the groundwater system include *recharge* zones (areas where water infiltrates from the surface and reaches the saturated zone), discharge points (locations where groundwater reaches the surface), unsaturated zones (the portion of the groundwater system above the water table), saturated zones (the portion of the groundwater system below the water table), and aquifers (water-bearing layers of rock that provide water in usable quantities). In combination, these characteristics define the quantity and quality of the available groundwater. This section also describes groundwater use as part of the system.

EVAPOTRANSPIRATION

Evapotranspiration is the loss of water by evaporation from the soil and other surfaces, including evaporation of moisture emitted or transpired from plants.

3.1.4.1 Surface Water

3.1.4.1.1 Regional Surface Drainage

Yucca Mountain is in the southern Great Basin, which generally lacks perennial streams and other surface-water bodies. The Amargosa River system drains Yucca Mountain and the surrounding areas (Figure 3-11). Although referred to as a river, the Amargosa and its tributaries (the washes that drain to it) are dry along most of their lengths most of the time. Exceptions include short stretches where groundwater discharges to or converges with the channel (DIRS 151945-CRWMS M&O 2000, p. 7.1-3); examples are near Beatty, Nevada; south of Tecopa, California; and in southern Death Valley, California. The river drains an area of about 8,000 square kilometers (3,100 square miles) by the time it reaches Tecopa (DIRS 103090-Bostic et al. 1997, pp. 103 and 112), and its course extends roughly 100 kilometers (60 miles) farther before it ends in the Badwater Basin in Death Valley (DIRS 151945-CRWMS M&O 2000, p. 7.1-2 and Figures 7.1-1 and 7.1-4, pp. F7.1-1 and F7.1-4), which is more than 80 meters (260 feet) below sea level (DIRS 151945-CRWMS M&O 2000, p. 2.2-1). The nearest surface-water impoundments are Peterson Reservoir, Crystal Reservoir, Lower Crystal Marsh, and Horseshoe Reservoir.

The largest of these is Crystal Reservoir, a manmade impoundment at Ash Meadows, which captures the discharge from several springs in the area and has a capacity of 1.8 million cubic meters (1,500 acre-feet). Crystal Reservoir and other smaller pools in Ash Meadows drain to the Amargosa River through Carson Slough (DIRS 151945-CRWMS M&O 2000, p. 7.1-2).

3.1.4.1.2 Yucca Mountain Surface Drainage

Occurrence. No perennial streams, natural bodies of water (DIRS 151945-CRWMS M&O 2000, pp. 7.1-2 and 7.1-3), or naturally occurring wetlands (DIRS 104592-CRWMS M&O 1999, p. 2-14) occur at Yucca Mountain or in the analyzed land withdrawal area. Fortymile Wash, a major wash that flows to the Amargosa River, drains the eastern side of Yucca Mountain (Figure 3-12) (DIRS 151945-CRWMS M&O 2000, p. 7.1-2). The primary washes draining to Fortymile Wash at Yucca Mountain include Yucca Wash to the north; Drill Hole Wash, which, together with its tributary, Midway Valley Wash, drains most of the repository site; and Busted Butte (Dune) Wash to the south. The western side of Yucca Mountain

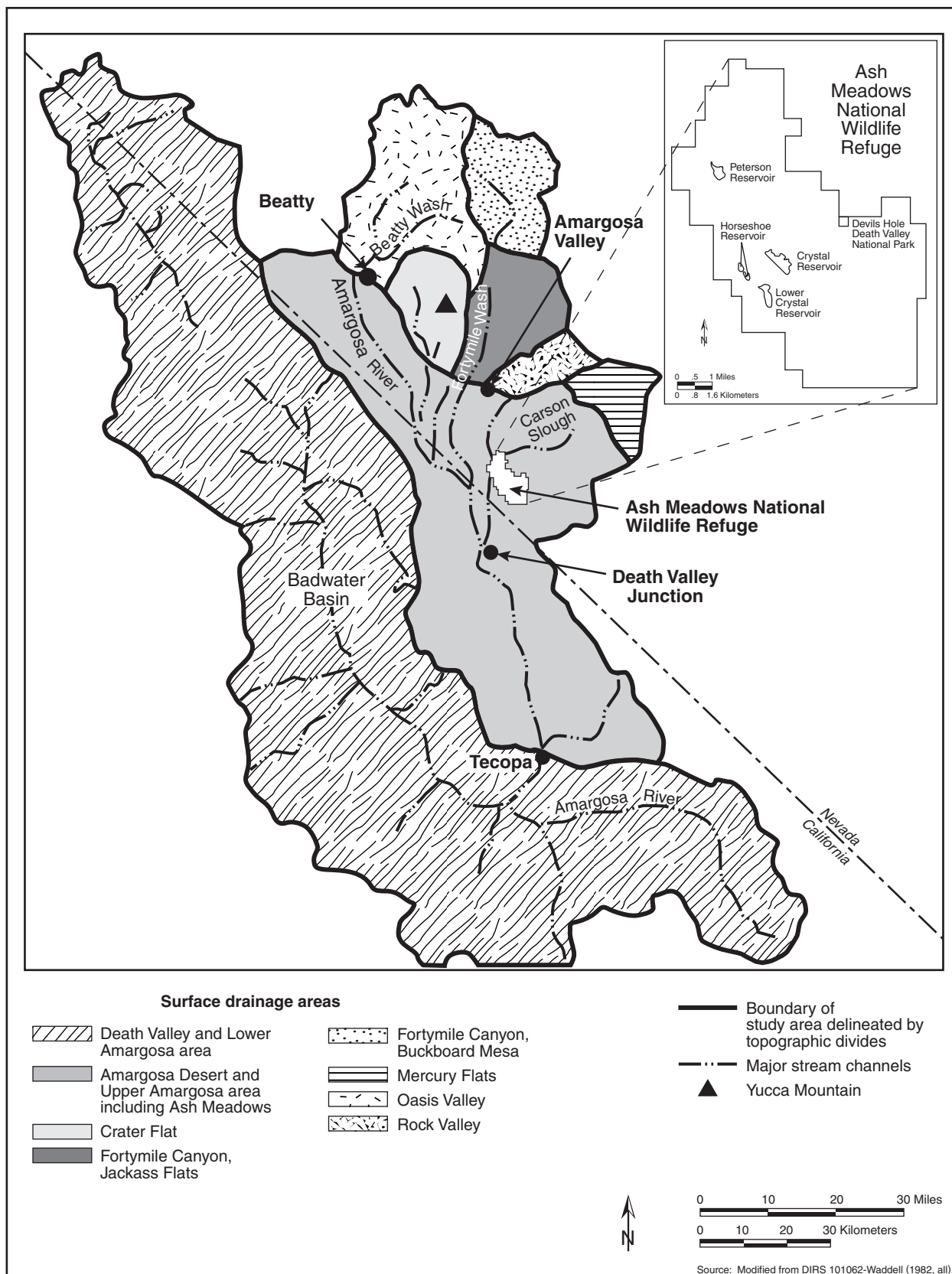


Figure 3-11. Surface areas drained by the Amargosa River and its tributaries.

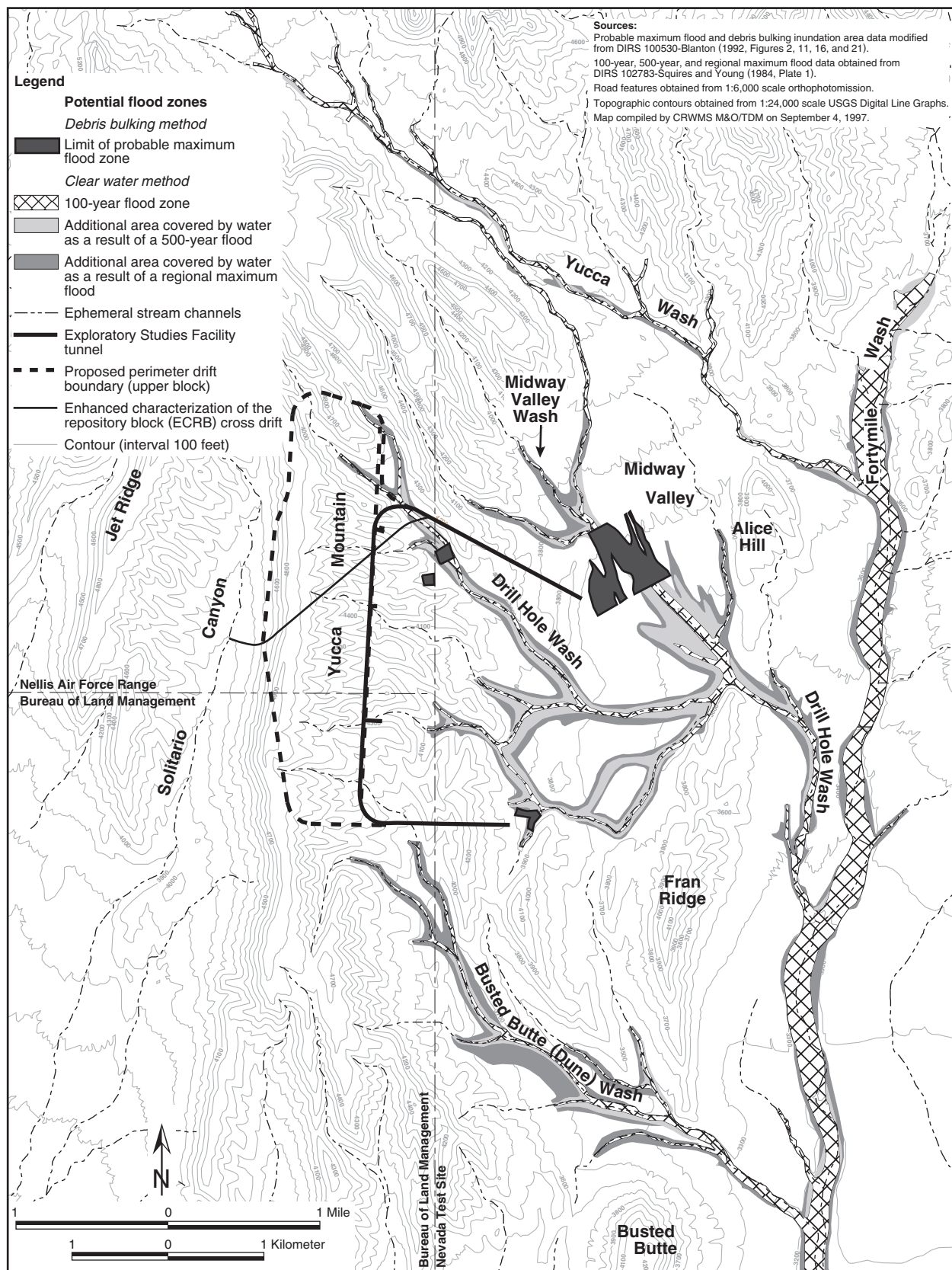


Figure 3-12. Site topography and potential flood areas.

is drained through Solitario Canyon Wash and Crater Flat, both of which eventually drain to the Amargosa River (DIRS 151945-CRWMS M&O 2000, p. 7.1-2). In this area, most of the water from summer storms is lost relatively quickly to evapotranspiration unless a storm is intense enough to produce runoff or subsequent storms occur before the water is lost (DIRS 151945-CRWMS M&O 2000, p. 7.5-1). Evapotranspiration is lower during the winter, when water from precipitation or melting snow has a better chance to result in stream flow.

Thunderstorms in the area can be local and intense, creating runoff in one wash while an adjacent wash receives little or no rain (DIRS 151945-CRWMS M&O 2000, p. 7.1-3). In rare cases, however, storm and runoff conditions can be extensive enough to result in flow being present throughout the drainage system. DIRS 155679-Glancy and Beck (1998, all) documented conditions during March 1995 and February 1998 where Fortymile Wash and the Amargosa River flow simultaneously through their primary channels to Death Valley. The 1995 event represented the first documented case of this flow condition. The 1995 event involved the higher recorded flows. The peak flow near the location where the existing Yucca Mountain access road crosses Fortymile Wash was reported as about 100 cubic meters (3,500 cubic feet) per second (DIRS 155679-Glancy and Beck 1998, p. 7). This flow is much less than that calculated as the *100-year flood* event for Fortymile Wash (as discussed in the next paragraph). The occurrence of flow throughout the drainage, however, might be a more unusual event because it would require the generation of runoff over a much larger area than the Fortymile Wash drainage, and in the same timeframe.

Flood Potential. Although flow in most washes is rare, the area is subject to flash flooding from intense summer thunderstorms or sustained winter precipitation (DIRS 151945-CRWMS M&O 2000, p. 7.3-1). When it occurs, intense flooding can include mud and debris flows in addition to water runoff (DIRS 100530-Blanton 1992, p. 2). Table 3-9 lists peak discharges for estimated floods along the main washes at Yucca Mountain, a value for a regional maximum flood. In addition to the flood estimates listed in the table, DOE used another estimating method, the *probable maximum flood* methodology [based on American National Standards Institute and American Nuclear Society Standards for Nuclear Facilities (DIRS 103071-ANS 1992, all)] to generate another maximum flood value for washes adjacent to the existing facilities and operations at the North and South Portals (DIRS 100530-Blanton 1992, all; DIRS 108883-Bullard 1992, all). The flood value this method generates, which includes a bulking factor to account for mud and debris (including boulder-size materials), is the most severe reasonably possible for the location under evaluation and is larger than the regional maximum flood listed in Table 3-9 (DIRS 151945-CRWMS M&O 2000, pp. 7.3-3 and 7.3-4). DOE used the probable maximum flood values to predict the areal extent of flooding and to determine if facilities and operations are at risk of flood damage.

PREDICTED FLOODS

100-year flood: The magnitude of peak discharge at any point on a river or drainage channel that can be expected to occur or be exceeded, on average, once in 100 years.

500-year flood: The magnitude of peak discharge at any point on a river or drainage channel that can be expected to occur or be exceeded, on average, once in 500 years.

Regional maximum flood: The magnitude of a peak discharge based on data from extreme floods, in this case, occurring elsewhere in Nevada and in nearby states.

Probable maximum flood: The hypothetical peak discharge considered to be the most severe reasonably possible based on a probable maximum precipitation and other factors favorable for runoff.

Figure 3-12 shows the extent of estimated floods calculated for the proposed repository before the construction of the Exploratory Studies Facility. It shows the area that the estimated 100- and 500-year

floods would inundate as well as the inundation area for the most conservative (highest) of the estimated maximum floods. As indicated on the figure, the partial or discontinuous inundation areas in Midway Valley Wash and the upper reaches of Drill Hole Wash are based on the probable maximum flood values derived in accordance with guidelines of the American National Standards Institute and American Nuclear Society; for other areas, the most extensive flood zones are based on the regional maximum flood levels listed in Table 3-9. The figure also shows that all floods along Fortymile Wash and Yucca Wash would remain within existing stream channels.

Table 3-9. Estimated peak discharges along washes at Yucca Mountain.^a

Name	Drainage area (square kilometers) ^b	Peak discharge 100-year flood (cubic meters per second) ^c	Peak discharge 500-year flood (cubic meters per second)	Regional maximum flood (cubic meters per second)
Fortymile Wash	810	340	1,600	15,000
Busted Butte (Dune) Wash	17	40	180	1,200
Drill Hole Wash ^d	40	65	280	2,400
Yucca Wash	43	68	310	2,600

a. Source: DIRS 102783-Squires and Young (1984, p. 2).

b. To convert square kilometers to square miles, multiply by 0.3861.

c. To convert cubic meters to cubic feet, multiply by 35.314.

d. Includes Midway Valley and South Portal Washes as tributaries—North and South Portal Areas.

Along Busted Butte (Dune) and Drill Hole Washes, the *500-year flood* would exceed stream channels at several places, and the probable maximum flood would inundate broad areas in Midway Valley Wash near the North Portal. None of the identified flood estimates predicts water levels high enough to reach either the North or South Portal opening to the subsurface facilities (DIRS 100530-Blanton 1992, pp. 4 and 7), which would be at either end of the Exploratory Studies Facility tunnel shown in the figure.

The U.S. Geological Survey (DIRS 103469-Thomas, Hjalmarson, and Waltemeyer 1997, all) recently published a revised methodology for calculating peak flood discharges in the southwestern United States. A preliminary evaluation indicates that the methodology, if appropriate for use, could result in estimates for 100-year floods that are larger than those listed in Table 3-8 and shown in Figure 3-12. However, the new methodology affects only the 100-year flood estimate, so discharge numbers and expanded inundation lines resulting from its use would be within the bounds set by the 500-year flood.

DOE has prepared a *floodplain* assessment for the Proposed Action in accordance with the requirements of 10 CFR Part 1022. Appendix L contains the floodplain assessment.

Surface-Water Quality. Samples of stream waters in the Yucca Mountain region have been collected and analyzed for their general chemical characteristics. Because surface-water flows are rare and in immediate response to storms, data from sampling events are sparse. Results of the surface-water sample analyses (Table 3-10) bear some resemblance to those from groundwater samples, as discussed in Section 3.1.4.2.2, because both contain bicarbonate as a principal component. However, in general, the groundwaters have a higher mineral content, suggesting more interaction between rock and water (see Section 3.1.4.2.2, Tables 3-13 and 3-17).

3.1.4.2 Groundwater

This section discusses groundwater, first on a regional basis and then in the Yucca Mountain vicinity. Many studies have been conducted on the groundwater system under and surrounding Yucca Mountain. These studies provide a firm basis of understanding of the hydrology of the region. However, because